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[54] **REFRIGERATING APPARATUS HAVING NOISE ATTENUATION**

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[73] Assignee: **Kabushiki Kaisha Toshiba**, Kawasaki, Japan

[21] Appl. No.: **666,049**

[22] Filed: **Mar. 7, 1991**

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Mar. 13, 1990 [JP] Japan 2-61712

[51] **Int. Cl.**[5] **F25D 19/00**; A61F 11/06

[52] **U.S. Cl.** **62/296**; 381/71; 417/14

[58] **Field of Search** 381/71, 94, 73; 62/296; 417/14

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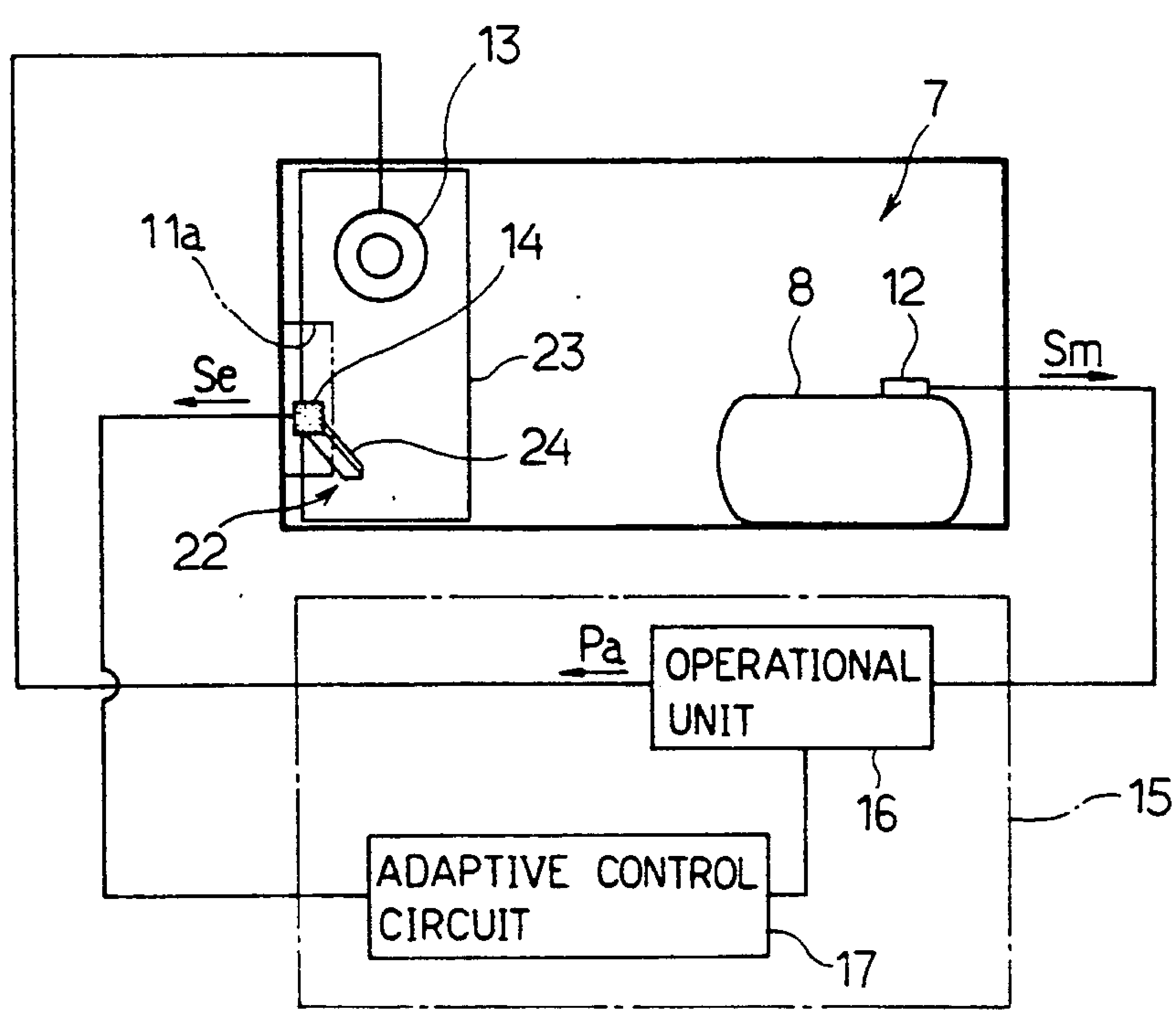
Primary Examiner—William E. Wayner
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

A refrigerator with a noise attenuating function includes a cabinet having storage and machine compartments, a compressor disposed in the machine compartment, a noise detector disposed in the machine compartment for detecting noise produced from driving of the compressor and converting the noise to an electrical signal, an operational unit for converting the electrical signal to an acoustic signal for an active noise control, a cancellation sound producer producing a sound of opposite phase with the noise based on the acoustic signal so that the noise is attenuated, a noise attenuation monitoring sound receiver for monitoring the noise attenuating effect of the cancellation sound producer, an adaptive control circuit changing an operational factor of the operational unit by a predetermined amount when the monitoring result of the noise attenuation monitoring sound receiver is out of a predetermined tolerance, the adaptive control circuit being adapted to continuously perform the operation of changing the operational factor until the monitoring result comes into the tolerance, and a connecting member for integrally connecting the cancellation sound producer and the noise attenuation monitoring sound receiver.

7 Claims, 6 Drawing Sheets



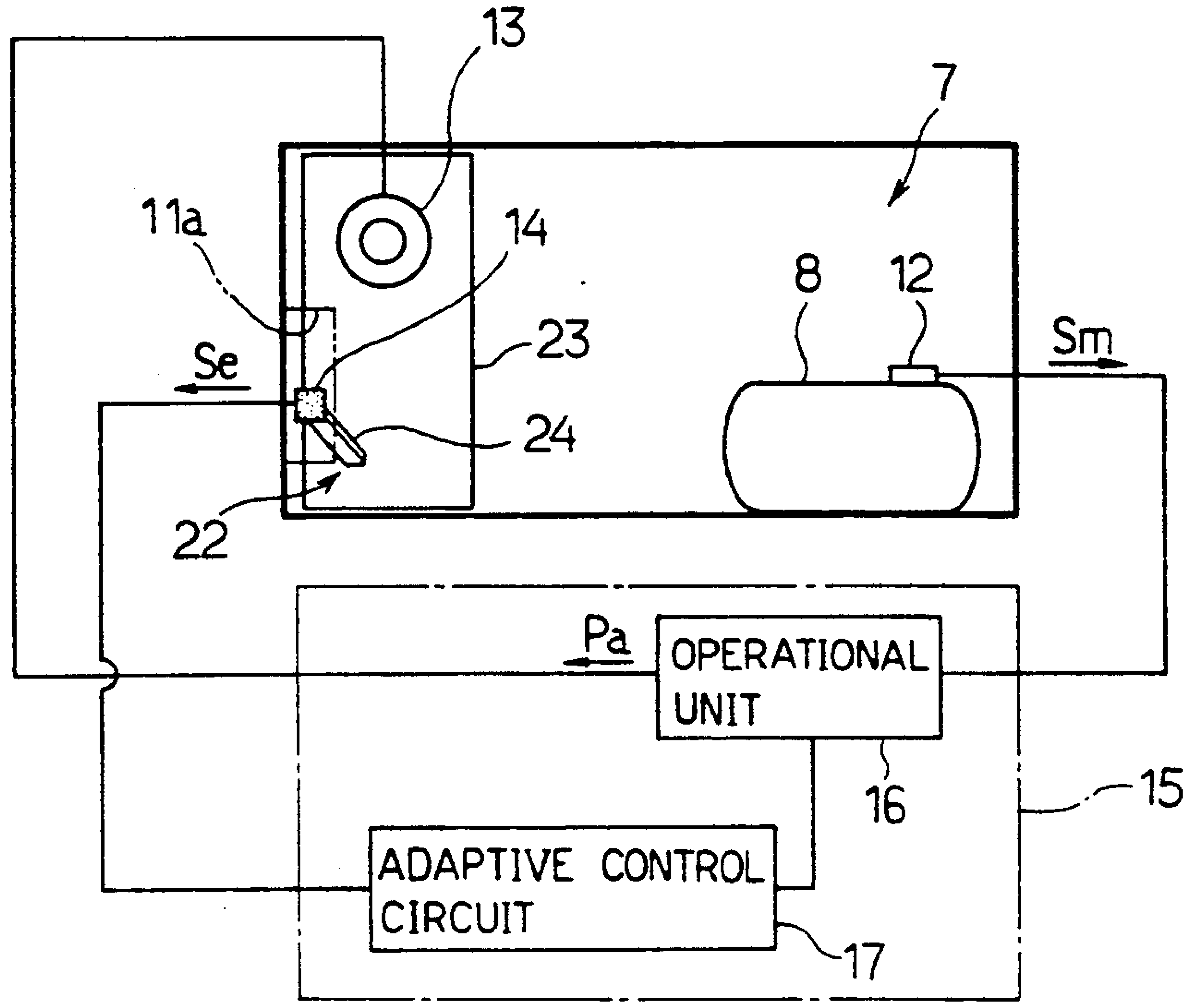

13
7
11a
14
8
12
Sm
Se
23
24
22
Pa
OPERATIONAL UNIT
16
15
ADAPTIVE CONTROL CIRCUIT
17

FIG. 1

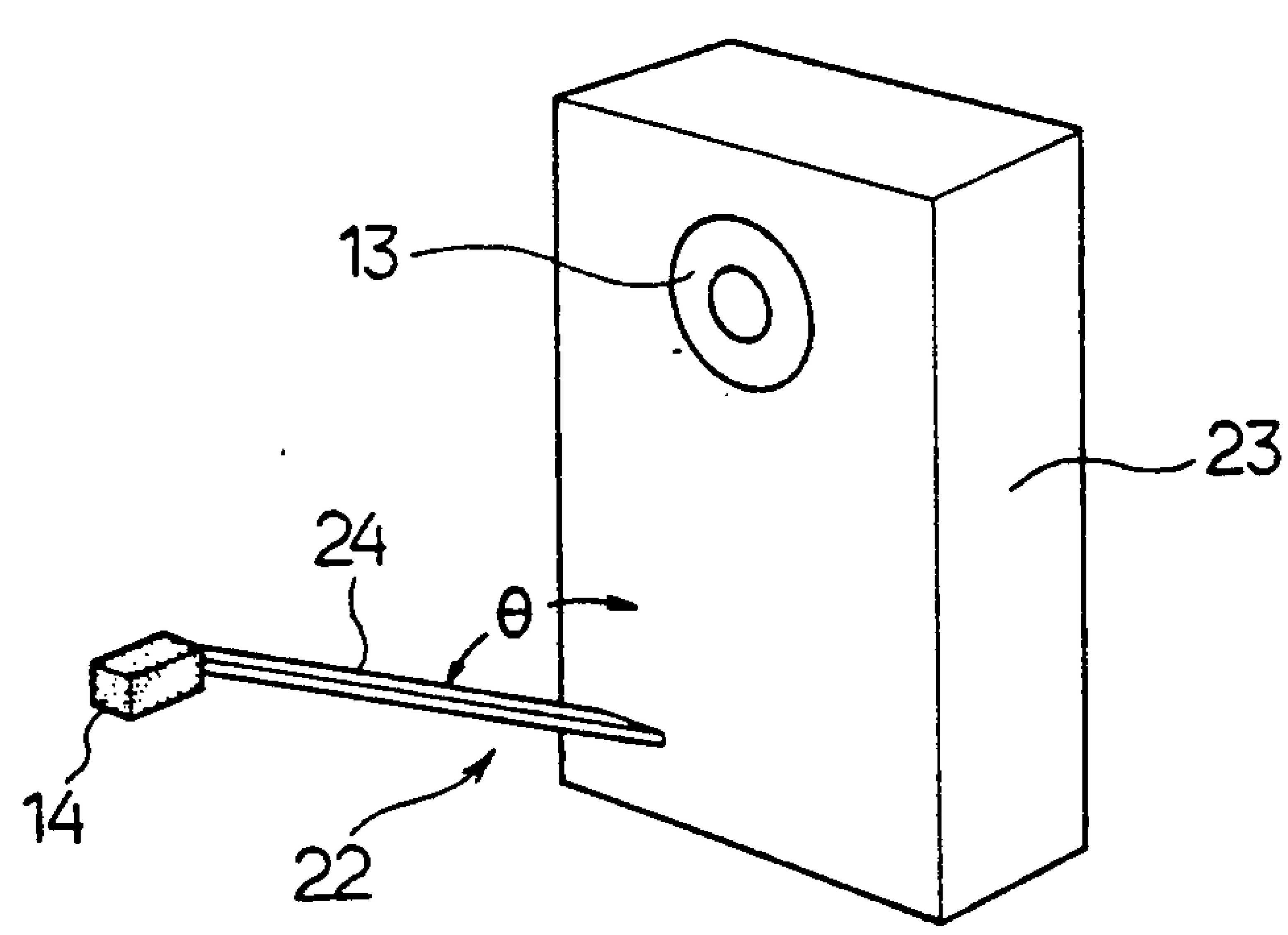

13
23
24
θ
14
22

FIG. 2

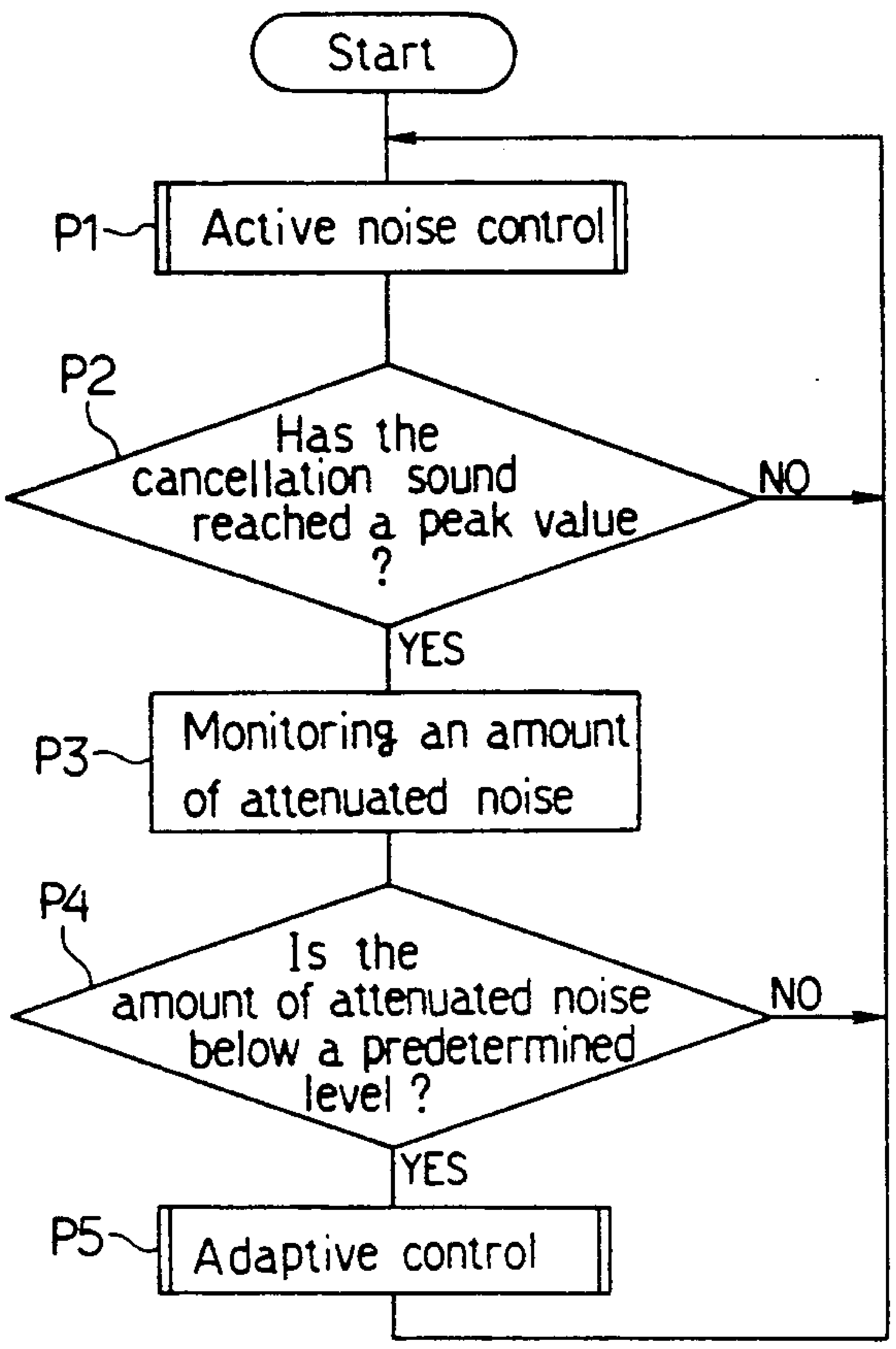

Start
P1
Active noise control
P2
Has the cancellation sound reached a peak value ?
NO
YES
P3
Monitoring an amount of attenuated noise
P4
Is the amount of attenuated noise below a predetermined level ?
NO
YES
P5
Adaptive control

FIG. 3

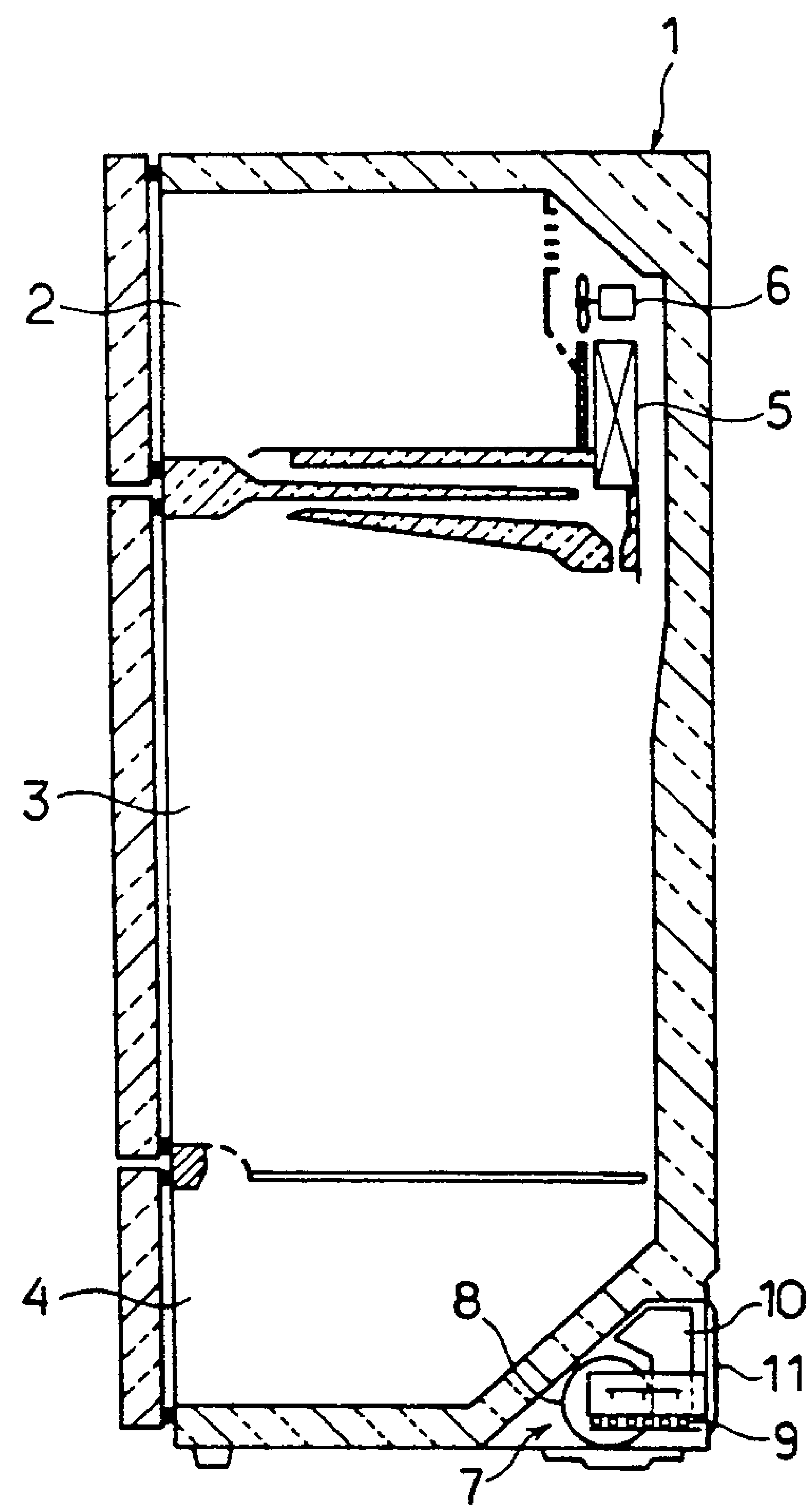

1
2
3
4
5
6
7
8
9
10
11

FIG. 4

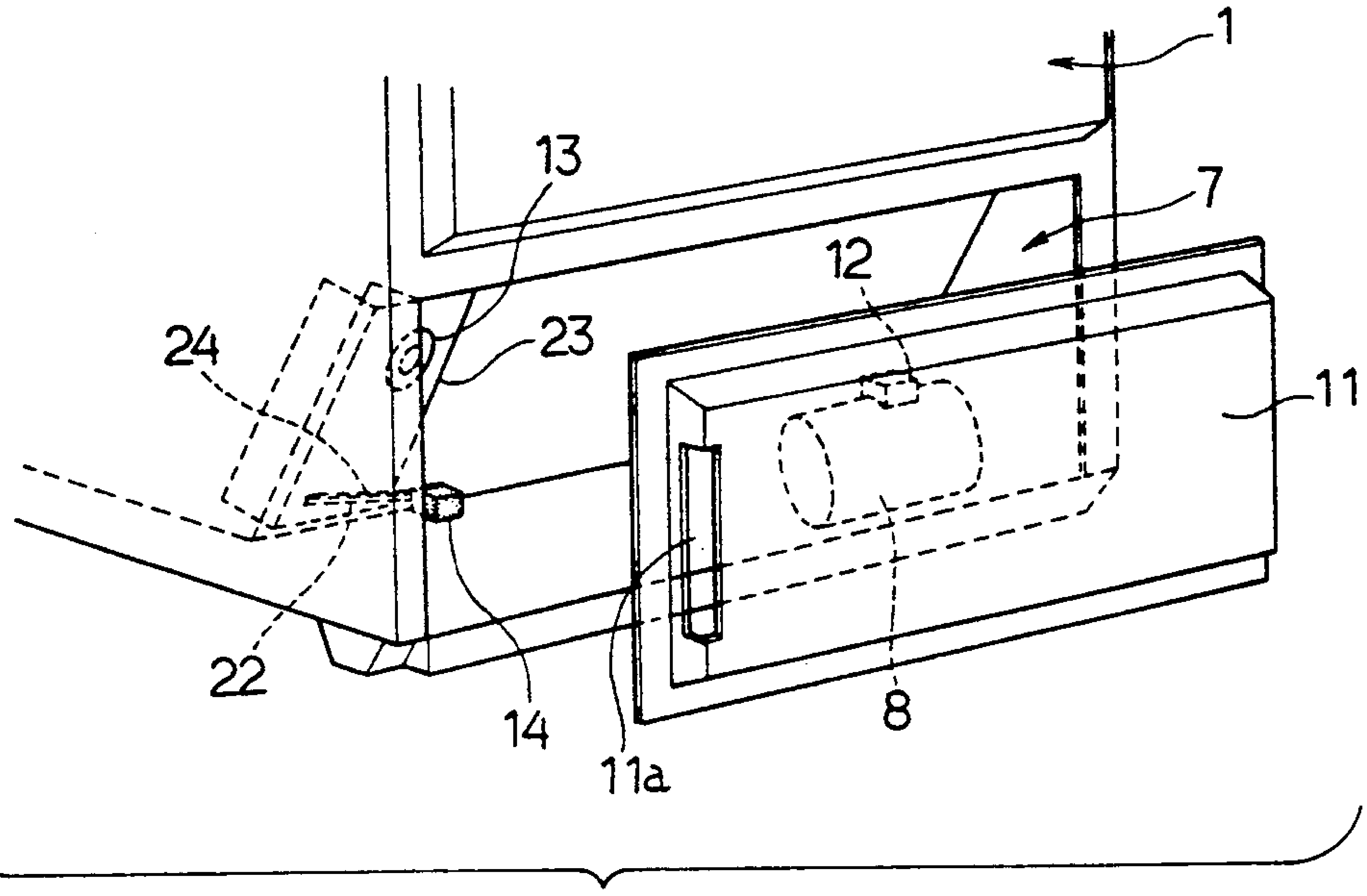

1
7
13
12
23
24
11
22
14
11a
8

FIG.5

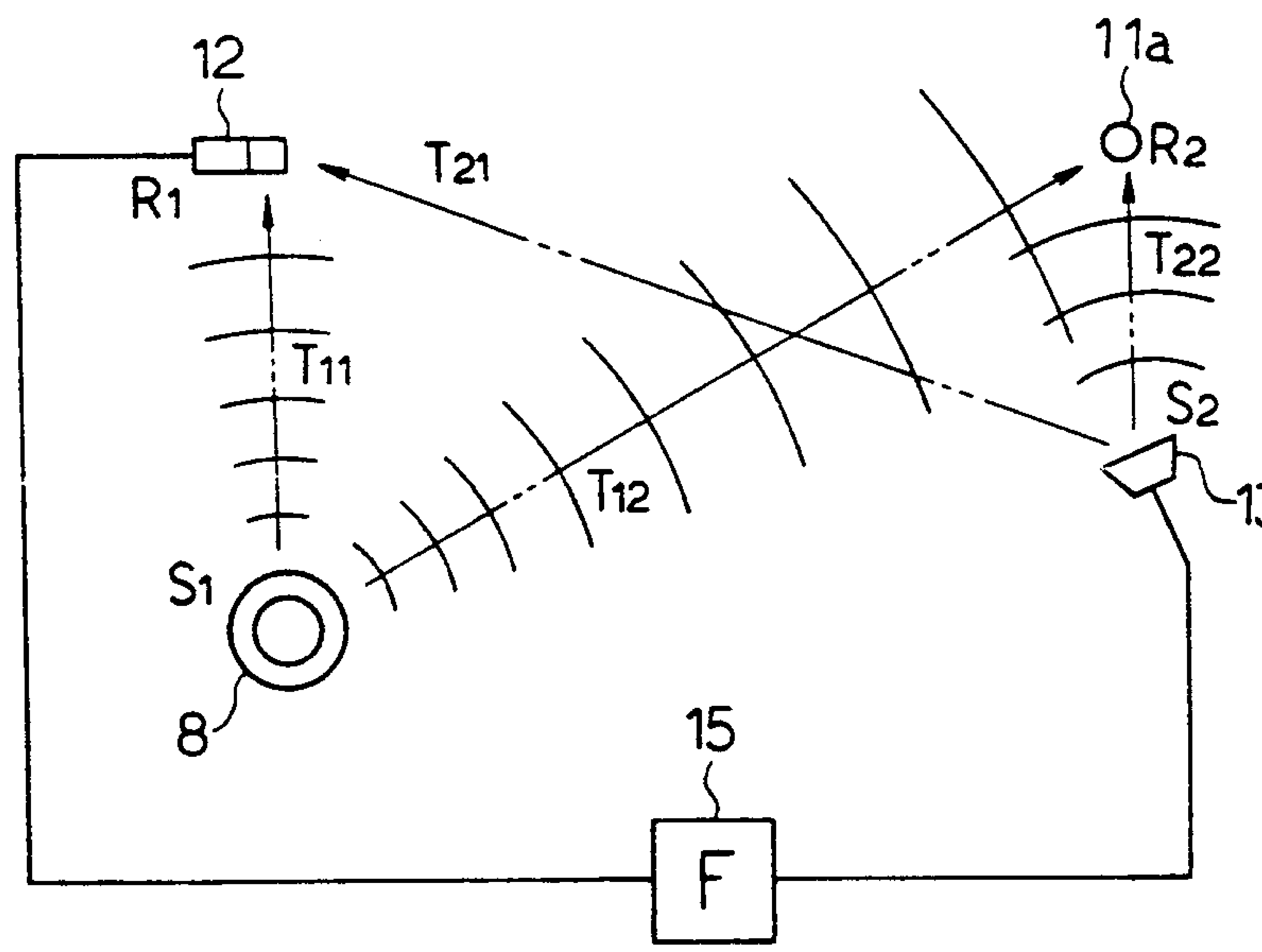

12
11a
R2
T21
R1
T22
T11
S2
T12
13
S1
8
15
F

FIG.6

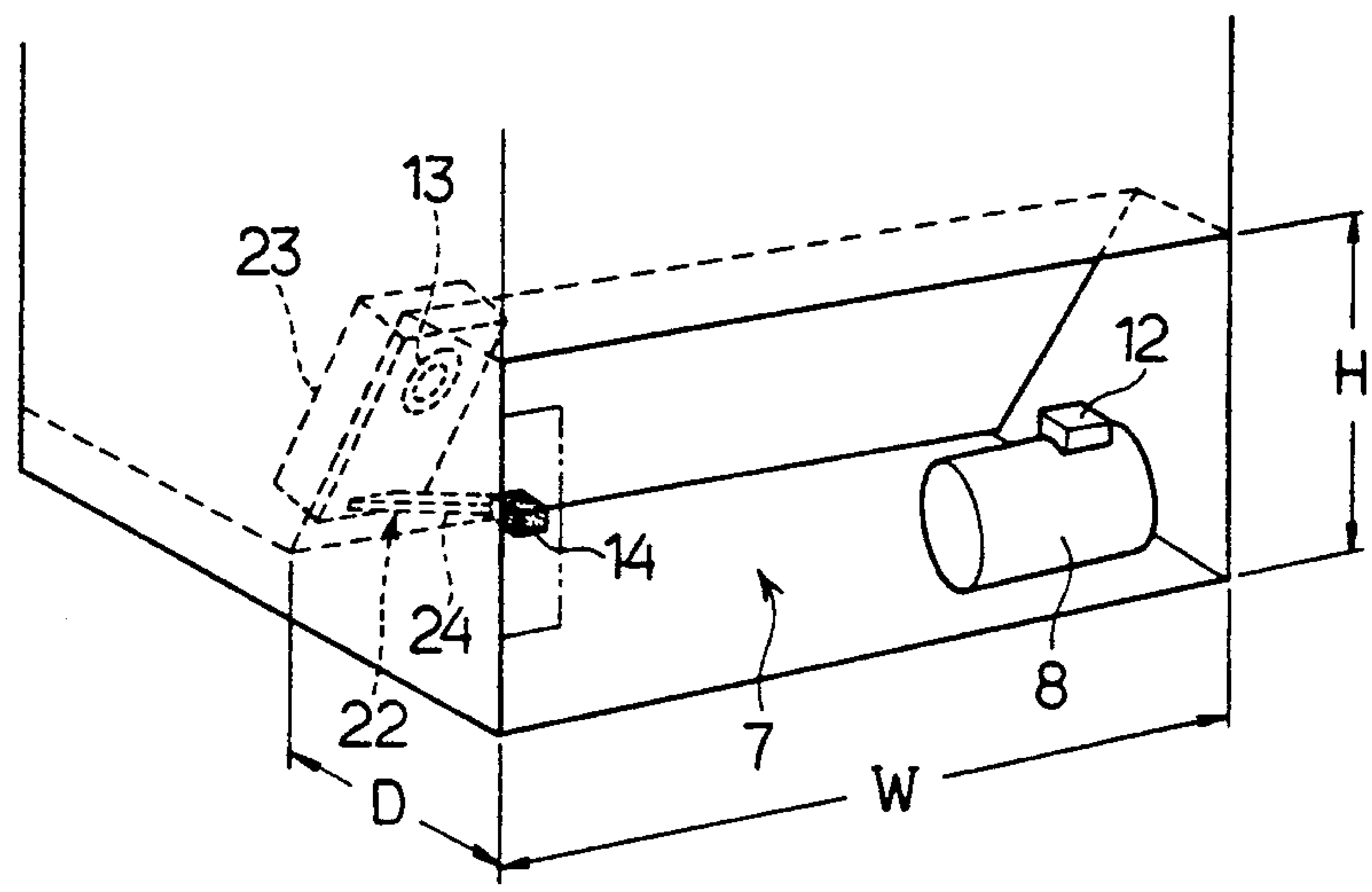


FIG.7

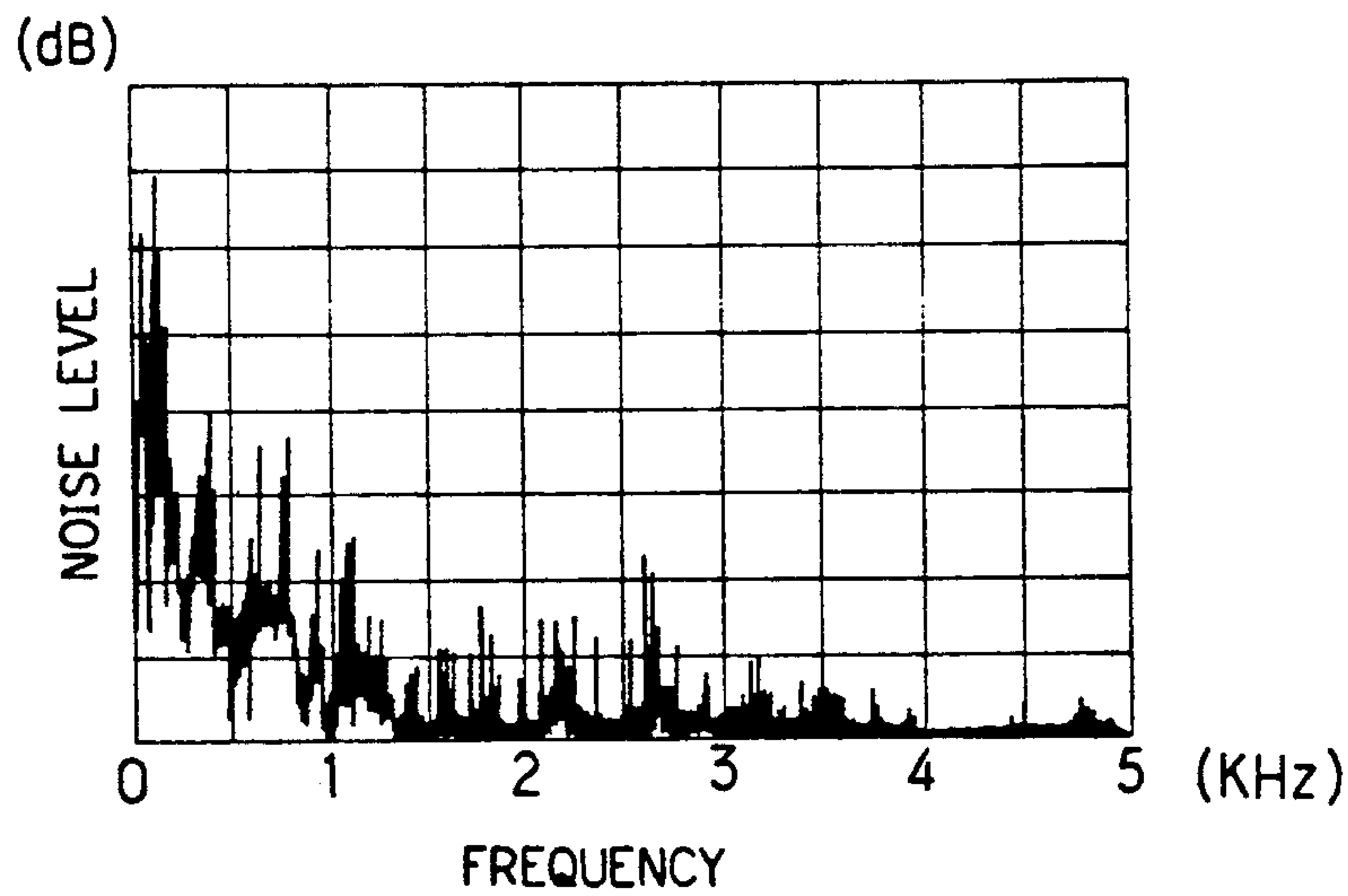


FIG.8

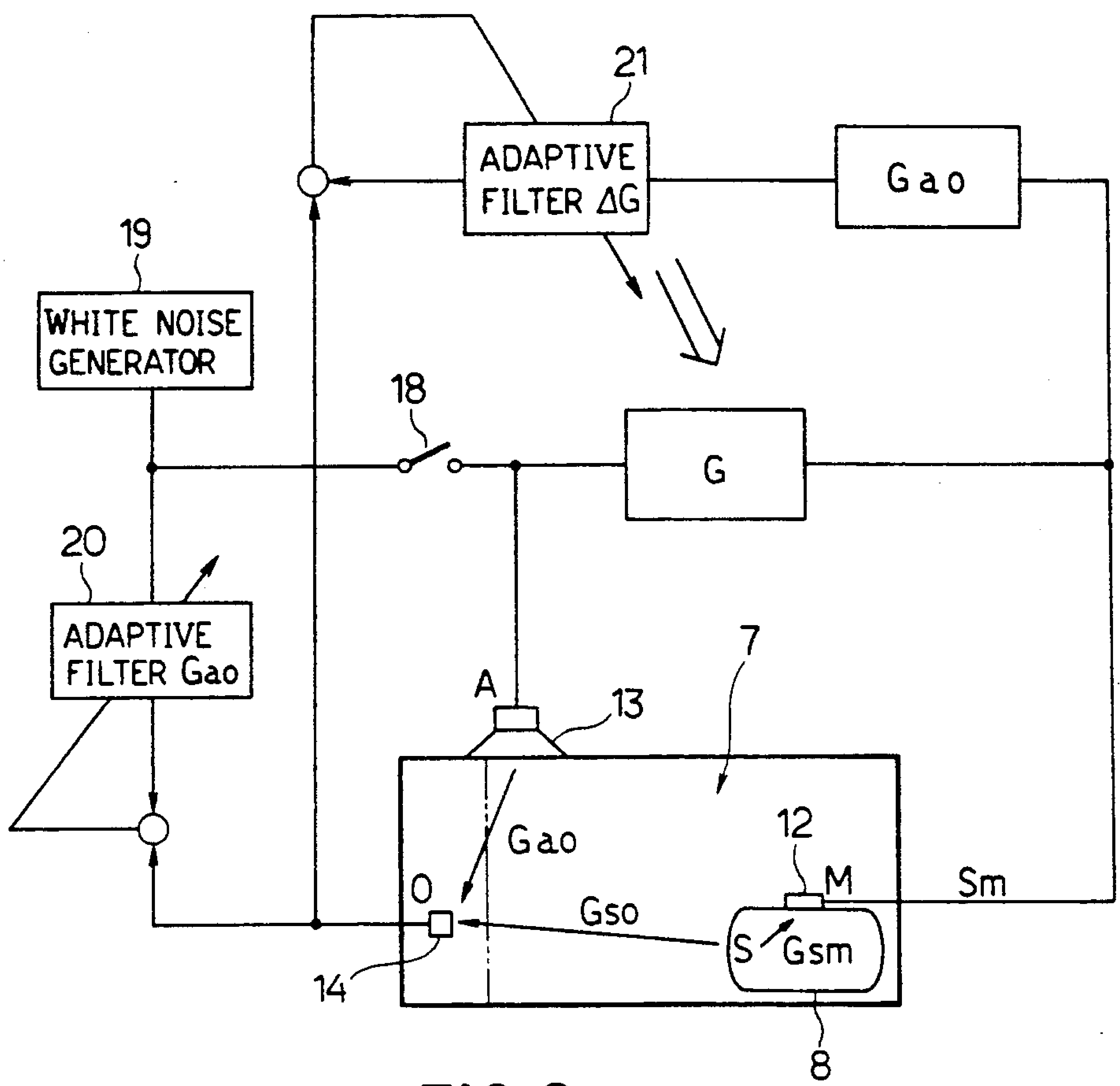

21
ADAPTIVE FILTER ΔG
Gao
19
WHITE NOISE GENERATOR
18
G
20
ADAPTIVE FILTER Gao
A
13
7
Gao
12
O
M
Sm
Gso
S
Gsm
14
8

FIG.9

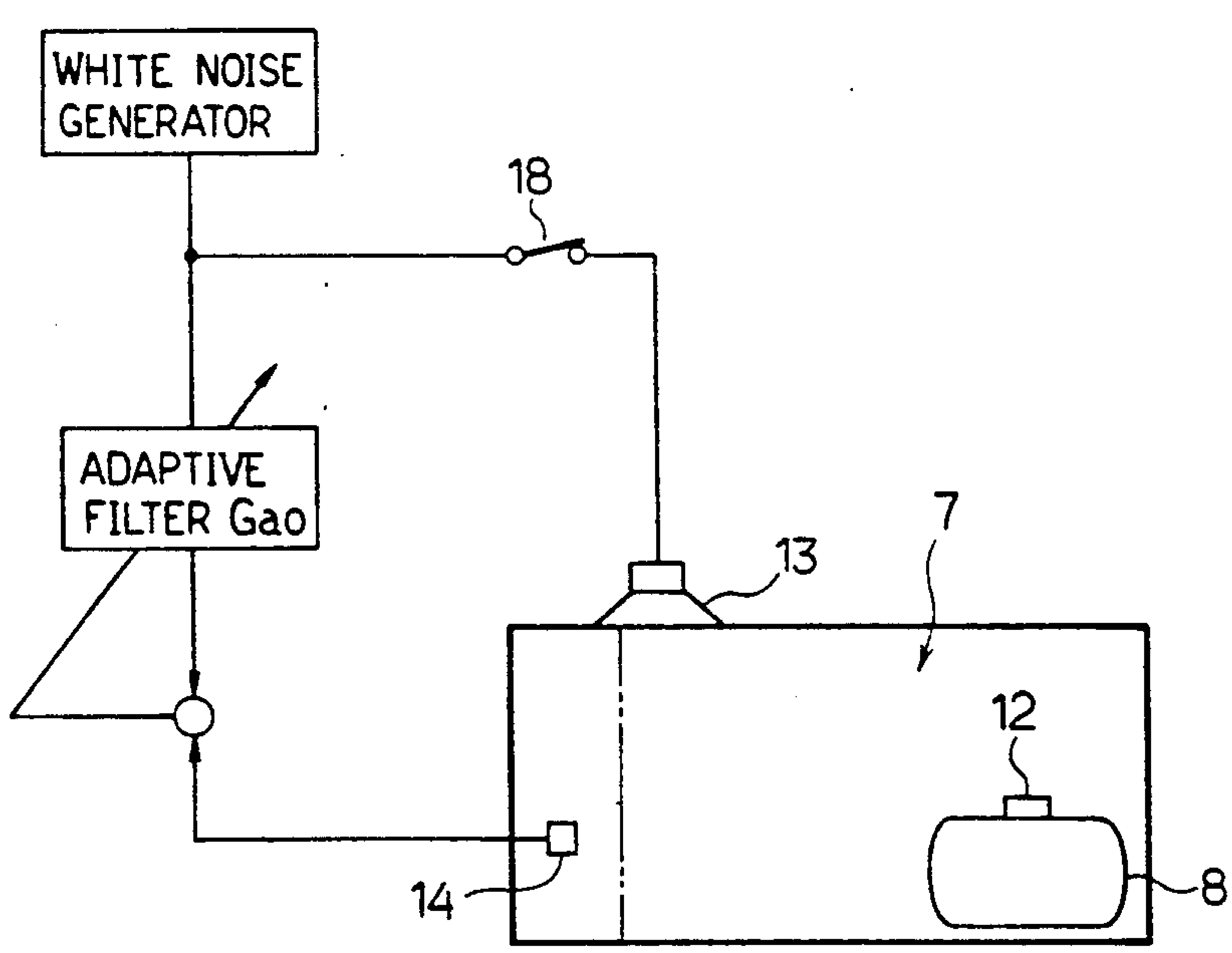

WHITE NOISE GENERATOR
18
ADAPTIVE FILTER Gao
13
7
12
14
8

FIG.10

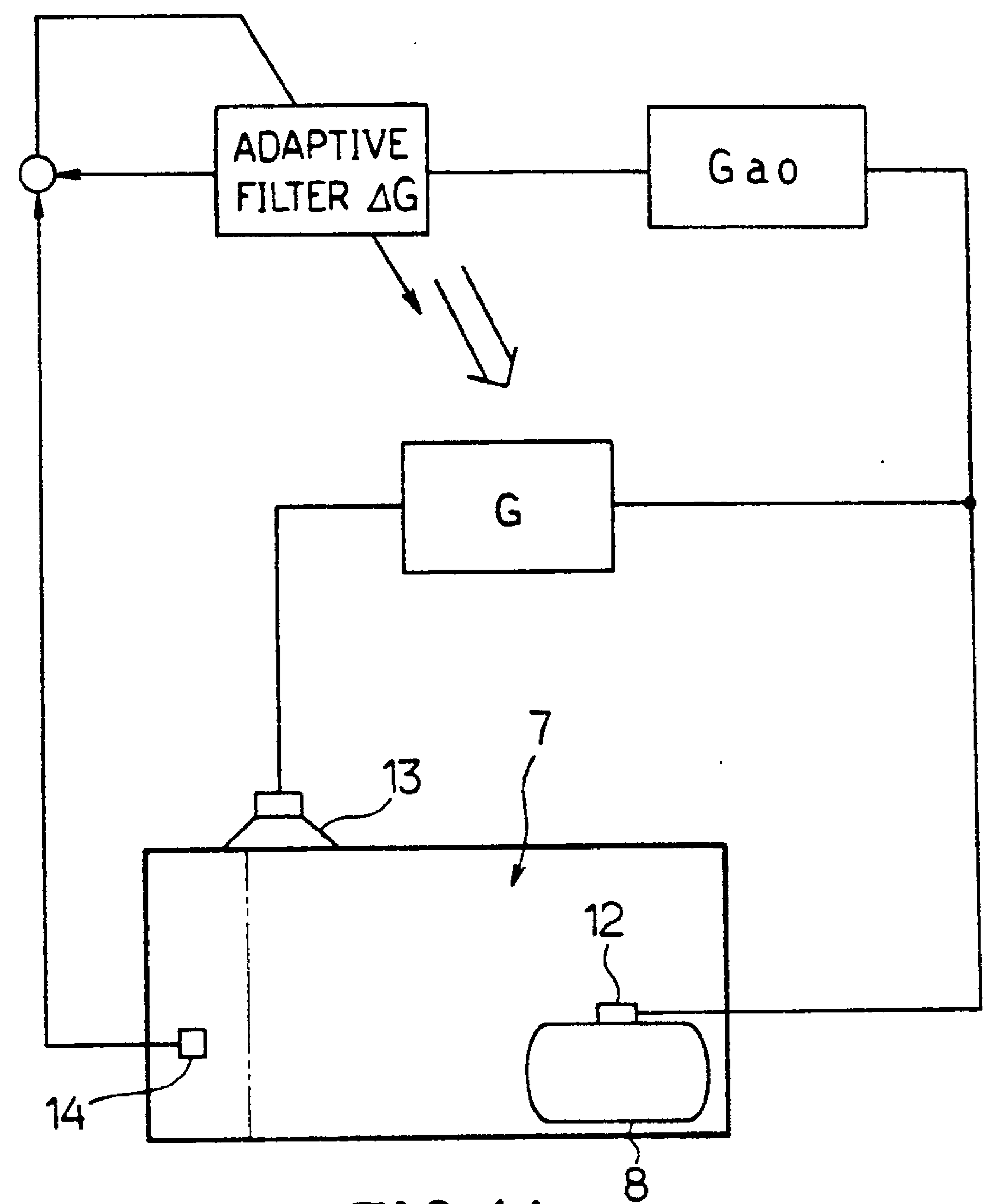


FIG.11

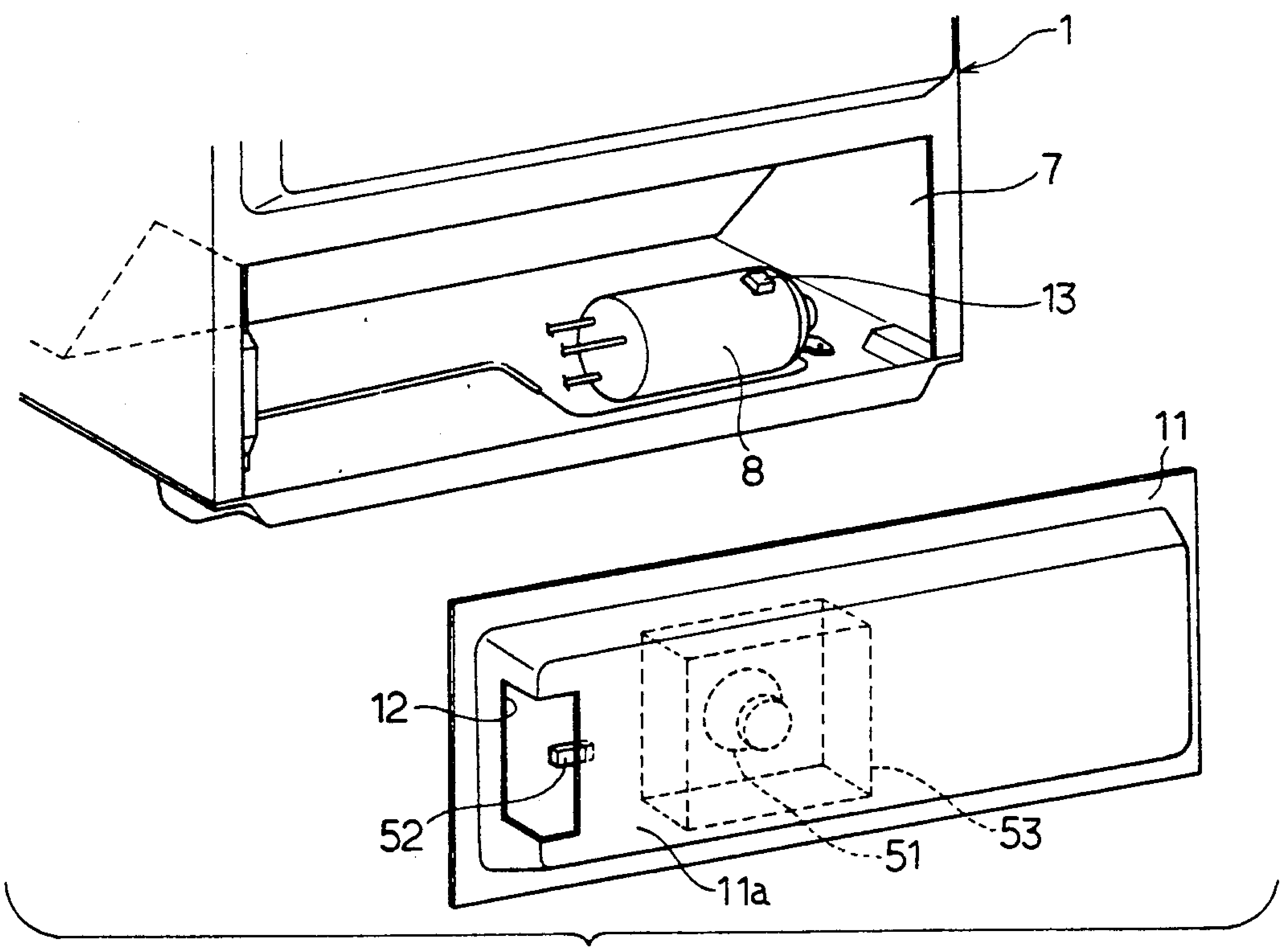


FIG.12

REFRIGERATING APPARATUS HAVING NOISE ATTENUATION

BACKGROUND OF THE INVENTION

This invention relates to a refrigerating apparatus such as a household refrigerator provided with a noise attenuating function actively attenuating noise produced from a compressor of the refrigerator or the like.

Almost every home is generally furnished with a refrigerating apparatus employing a compressor, for example, a household refrigerator. Since such a refrigerator is in continuous operation throughout the year, it is important to solve a problem of noise produced therefrom. In the refrigerator, one critical noise source is a machine compartment enclosing a compressor and piping system connected to the compressor. More specifically, from the machine compartment emanates a relatively loud noise, for example, a noise produced from driving of a compressor motor, noise produced from the flow of a compressed gas and mechanical noise produced by moving members of a compression system. Furthermore, the piping system connected to the compressor produces noise due to vibration thereof. The noises emanating from the machine compartment thus account for a large part of the noise of the refrigerator. Accordingly, control of the noise from the machine compartment contributes to noise reduction in the refrigerator.

Conventionally, compressors of the low noise type such as a rotary compressor have been employed for the purpose of reducing the noise emanating from the machine compartment. Further, the construction of vibration-proofing of the compressor has been improved and the configuration of the piping has been improved, thereby providing damping of the vibration in a vibration transfer path. Further, noise absorptive and insulative members have been disposed around the compressor and piping system, thereby improving an amount of noise absorbed in the machine compartment and a noise transfer loss.

However, a plurality of ventilating openings are formed in one or more walls defining the machine compartment for ventilating the machine compartment, and the noise produced in the machine compartment leaks outward through the ventilating openings. As the result of the provision of the ventilating openings, the above-mentioned conventional noise-reduction methods each have a definite limit and provide at most noise reduction of 2 dB.

With the advancement of applied electronic techniques including sound data processing circuitry and acoustic control techniques, application of an active noise control system wherein noise is attenuated by the effect of sound wave interference has recently been taken into consideration. More specifically, in the above-mentioned active noise control system, detection means such as a microphone is provided at a specific position in the machine compartment for receiving sound emanating from a noise source and converting the received noise to a corresponding electrical signal. The electrical signal is then processed to a cancellation signal by an operational unit. The cancellation signal is supplied to a cancellation sound producer such as a speaker so that an artificial cancellation sound of opposite phase or 180° out of phase with the noise received by the microphone and having the same frequency and amplitude as that of the received noise is produced by the speaker, so that the artificial sound interferes with the received noise, thereby attenuating the noise.

When the above-described active noise control system is put to a practical use, it is necessary to compensate for variations of characteristics of a noise attenuating signal system due to both aged deterioration of parts composing the signal system and the ambient temperature. For this purpose, it is proposed that an operational factor or acoustical transfer function be compensated for in accordance with variations of the noise attenuating capability of the active noise control system. To perform such a compensation, it is proposed that a noise attenuation monitoring sound receiver such as a microphone be provided for monitoring a sound attenuation effect of the control sound producer and that control means is provided for changing the operational factor of the operational unit by a predetermined amount when the monitoring result shows that the operational factor is out of a predetermined tolerance. The control means is adapted to continuously perform the operation of changing the operational factor until the operational factor comes into the tolerance. Such a control is referred to as an adaptive control wherein the noise attenuation effect in the active noise control is maintained at an optimum level.

To perform a desirable adaptive control, the noise attenuation monitoring sound receiver needs to be disposed away from the cancellation sound producer accurately by a preselected distance. Actually, however, variations in the distance between the monitoring sound receiver and the cancellation sound producer during assembly steps, which reduces the accuracy of the adaptive control. When the assembly accuracy is improved such that the variations in the distance between the monitoring sound receiver and the cancellation sound producer can be ignored, the accuracy of jigs used to mount the receiver and producer needs to improved and a careful assemblage is needed, resulting in lowered working efficiency and increased production cost.

SUMMARY OF THE INVENTION

Therefore, an object of the present invention is to provide a refrigerating apparatus provided with a noise attenuating function wherein the noise produced from driving of the compressor is actively attenuated, the noise attenuating operation is controlled in the manner of the adaptive control based on the monitoring result of the noise attenuation monitoring sound receiver, the accuracy in the positional relationship between the cancellation producer and the monitoring sound receiver can be readily improved without using specific jigs, and the accuracy in the active noise control can be improved with the improvement of the assembling efficiency and the cost reduction.

To achieve the above-described object, the present invention provides a refrigerating apparatus with a noise attenuating function comprising a heat-insulative cabinet having a storage compartment and a machine compartment, a compressor provided in the machine compartment, sound detection means provided in the machine compartment for detecting noise produced from driving of the compressor and converting the detected noise to a corresponding electrical signal, an operational unit for converting the electrical signal to an acoustic signal for an active noise control, a cancellation sound producer producing a sound of opposite phase with the noise based on the acoustic signal so that the noise is attenuated, a noise attenuation monitoring sound receiver for monitoring a noise attenuating effect of the cancellation sound producer, an adaptive control circuit changing an operational factor of the operational unit by a predetermined amount when the monitoring result of the noise attenuation monitoring sound receiver is out of a predetermined tolerance, the adaptive control circuit being adapted to continuously perform the operation of changing the operational factor until the monitoring result comes into the tolerance, and a connecting member for integrally connecting the cancellation sound producer and the noise attenuation monitoring sound receiver.

Since the cancellation sound producer and noise attenuation monitoring sound receiver are integrally connected by the connecting member, they may be built into the refrigerating apparatus without using any specific jig with a predetermined positional relationship therebetween exactly maintained, which prevents occurrence of variations in the distance between them and improves the accuracy of the adaptive control.

Preferably, the machine compartment may have a rear cover detachably mounted thereon so that a rear opening of the compartment is closed and the rear cover may also serve as the connecting member for integrally connecting the cancellation sound producer and the noise attenuation monitoring sound receiver. Upon detachment of the rear cover from the machine compartment, the cancellation sound producer and the noise attenuation monitoring sound receiver may also be detached with the rear cover. This construction is advantageous in that the inspection, repair and replacement of these members may be performed with ease.

It is preferable that the cancellation sound producer be embedded in an insulative wall defining the machine compartment. Since the cancellation sound producer can be rigidly secured by the machine compartment wall, frequency characteristics of the cancellation sound produced by the same can be improved.

It is also preferable that the sound detection means comprise a vibration sensor mounted on the compressor. Since the noise produced from driving of the compressor as a noise source can be directly sensed by the vibration sensor, the accuracy of the noise detection can be improved.

It is further preferable that one of dimensions of the machine compartment in the directions of the length, height and width thereof be set at a value larger than those of the others such that a standing wave of the sound is composed only in said one direction. In this construction, the noise produced in the machine compartment may be considered a one-dimensional plane traveling wave and consequently, the theoretical handling of the noise in the active noise control can be simplified.

It is further preferable that the rear cover of the machine compartment have a ventilating opening formed therein so as to be away from the compressor and the noise attenuation monitoring sound receiver be disposed in the vicinity of the ventilating opening in the machine compartment. In this construction, the noise attenuating effect can be improved.

It is further preferable that the rear cover of the machine compartment be formed of a material having fine heat-conductivity and large sound-transfer loss property. This construction improves the heat radiating effect and prevents the noise leakage from the rear cover.

Other objects of the present invention will become obvious upon understanding of the illustrative embodiment about to be described or will be indicated in the appended claims. Various advantages not referred to herein will occur to one skilled in the art upon employment of the invention in practice.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically illustrates an active noise attenuation system of an embodiment of the invention;

FIG. **2** is a perspective view of a cancellation sound producer and noise attenuation monitoring sound receiver integrated with the producer;

FIG. **3** is a flowchart for explaining the noise attenuating operation;

FIG. **4** is a longitudinal section of a refrigerator to which the active noise attenuation system is applied;

FIG. **5** is an exploded perspective view of a machine compartment of the refrigerator;

FIG. **6** schematically illustrates the noise attenuation principle by the active noise control;

FIG. **7** is a schematically perspective view of the machine compartment for explaining the dimensions thereof;

FIG. **8** is a graph showing noise level characteristics of the noise produced from driving of the compressor;

FIG. **9** is a block diagram schematically illustrating the principle of an adaptive control;

FIGS. **10** and **11** are views similar to FIG. **9** showing operations of the adaptive control, respectively; and

FIG. **12** is an exploded perspective view of the machine compartment to which the active noise attenuation system of a second embodiment is applied.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment in which the present invention is applied to a refrigerator will be described with reference to the accompanying drawings. Referring first to FIG. **4** showing an overall construction of the refrigerator, reference numeral **1** designates a heat-insulative cabinet of the refrigerator. The interior of the refrigerator cabinet **1** is partitioned to a freezing compartment **2**, a storage compartment **3** and a vegetable compartment **4** successively from the top. An evaporator **5** is provided at the backside of the freezing compartment **2**. A fan **6** is provided for directly supplying a chilled air to the freezing and storage compartments **2**, **3**. A machine compartment **7** is provided at the lower backside of the refrigerator cabinet **1**. The machine compartment **7** encloses a rotary type compressor **8**, a condenser pipe **9** and a defrost-water vaporizer **10** employing ceramic fins. During driving of the compressor **8**, a refrigerant from the compressor **8** is supplied through a refrigerant path (not shown) to the evaporator **5** which evaporates the refrigerant and the fan **6** is driven so that the heat exchange is performed between the evaporator **5** and the refrigerator interior.

As shown in FIG. **5** wherein the condenser pipe **9** and defrost-water vaporizer **10** are eliminated, the machine compartment **7** has at the backside a generally rectangular opening which is closed by a machine compartment cover **11**. In closing the opening of the machine compartment **7**, the periphery of the cover **11** is air-tightly attached against the opening edge of the machine compartment **7**. A generally slenderly rectangular ventilating opening **11**a extending vertically is formed in the left-hand edge portion of the cover **11**, as viewed in FIG. **5**. Thus, when the cover **11** is attached to the machine compartment **7**, it is closed except the ventilating opening **11**a. The cover **11** is formed of a hard material having good heat-conductivity and large sound-transfer loss properties, such as a metal like steel.

Further referring to FIG. **5**, a vibration sensor **12** serving as sound detecting means is mounted on the compressor **8** for detecting a vibrational sound produced from the compressor with vibration thereof and converting the detected sound to a corresponding electrical signal. A speaker **13** serving as a cancellation sound producer is provided in the machine compartment **7**. The speaker **13** is, for example, mounted in a portion of a machine compartment inner wall corresponding to the bottom wall of the refrigerator cabinet **1**, the portion being in the vicinity of the ventilating opening **11**a, as will be described later. A microphone **14** serving as a noise attenuation monitoring sound receiver is disposed in the vicinity of the ventilating opening **11**a, as will be described later. The microphone **14** is adapted to receive an interference sound caused by the interference of the noise from the compressor **8** and the cancellation sound from the speaker **13** for monitoring the noise attenuation effect of the sound from the speaker **13**.

Referring to FIG. **1**, the electrical signal S_m generated by the vibration sensor **12** is processed by an operational unit **16** in an opposite phase sound producing circuit **15** into a control signal P_a, which signal is supplied to the speaker **13** for activating the same. The above-mentioned processing of the electrical signal S_m is performed based on the following principle of the noise attenuation by the active noise control: referring to FIG. **6**, the following equation holds for two-input and two-output system:

$$\begin{bmatrix} R_1 \\ R_2 \end{bmatrix} = \begin{bmatrix} T_{11} & T_{21} \\ T_{12} & T_{22} \end{bmatrix} \begin{bmatrix} S_1 \\ S_2 \end{bmatrix}$$

where

S_1 = sound produced from the compressor **8**

S_2 = sound produced from the speaker **13**

R_1 = vibrational sound sensed by the vibration sensor **12**

R_2 = sound received by the microphone 14 disposed at the ventilating opening 11a as a control point

T_{11}, T_{21}, T_{12}, T_{22} = acoustic transfer functions between input and output points of the respective sounds

Accordingly, the sound S_2 to be produced from the speaker **13** is obtained from the following equation:

$$S_2 = (-T_{12} \cdot R_1 + T_{11} \cdot R_2)/(T_{11} \cdot T_{22} - T_{12} \cdot T_{21})$$

Since the goal is to reduce the acoustic level at the control point to zero, zero is substituted for R_2 as follows:

$$S_2 = R_1 \cdot T_{12}/(T_{12} \cdot T_{21} - T_{11} \cdot T_{22})$$

As is understood from this equation, in order to render R_2 zero, the sound R_1 detected by the vibration sensor **12** may be processed by a filter expressed by the following equation:

$$F = T_{12}/(T_{12} \cdot T_{21} - T_{11} \cdot T_{22}) \quad (1)$$

When a processed sound S_2 thus obtained is produced from the speaker **13**, the sound level at the ventilating opening **11**a can be theoretically rendered zero. The operational unit **16** is adapted to perform the above-described sound processing at a high speed and supply a control signal Pa to the speaker **13**.

Substituting G, G_{so}, G_{am}, G_{sm} and G_{ao} for F, T_{12}, T_{21}, T_{11} and T_{22} in the equation (1), respectively,

$$G = G_{so}/(G_{so} \cdot G_{am} - G_{sm} \cdot G_{ao}) \quad (2)$$

In the equation (**2**), each first subscript in G_{so}, G_{am}, G_{sm} and G_{ao} denotes an input side and each second subscript an output side or response side. For example, G_{am} represents an acoustic transfer function in the case where an input signal to the speaker **13** is the input side and an output signal from the microphone **14** the output side. Since the sound from the speaker **13** is not received by the vibration sensor **12** in the arrangement that the noise from the compressor **8** is detected by the vibration sensor **12**, G_{am} can be considered zero. Accordingly, the equation (2) is represented as follows:

$$G = -G_{so}/(G_{sm} \cdot G_{ao}) \quad (3)$$

Since $G_{so}/G_{sm} = G_{mo}$, the equation (3) is represented as follows:

$$G = -G_{mo}/G_{ao} \quad (4)$$

That is, when the sound obtained by processing the electrical signal from the vibration sensor **12** by use of a filter corresponding to G represented by the equation (4) is produced from the speaker **13**, an acoustic level at the ventilating opening **11**a can be theoretically rendered zero.

When the compressor **8** in the refrigerator constructed as described above is driven, the noise level in the machine compartment **7** has a characteristic that the noise level is increased in the frequency band below 700 Hz and in the frequency bands between 1.5 and 5 kHz, as shown in FIG. **8**. Of the noises in the respective frequency bands, the high frequency noise can be damped by way of the acoustic transfer loss through the machine compartment cover **11** and the like and readily dissipated by providing a sound absorption member in the machine compartment **7**. Accordingly, the active noise control by way of the vibration sensor **12**, speaker **13** and operational unit **16** is aimed at the noise having frequencies below 700 Hz.

In performing the above-described active noise control, it is important that the machine compartment **7** be constructed so that the noise in the compartment is composed to be a one-dimensional plane traveling wave, whereby the noise control is performed with ease and accuracy theoretically and technically. In the embodiment, for example, the width W or transverse dimension of the machine compartment **7** is determined so as to take a value larger than those of the depth D or front-to-back dimension and the height H or longitudinal dimension thereof, as shown in FIG. **7**. More definitely, the width W is determined to be 600 mm and each of the depth D and height H is determined to be 200 mm. In other words, the dimension of the width W is approximated to the wavelength of the noise to be attenuated and the dimensions of the depth and height are rendered shorter than the wavelength of the noise to be attenuated such that a standing wave of the noise in the machine compartment 7 holds only for a primary mode. When the machine compartment 7 is considered a rectangular cavity, for example, the following equation holds:

$$f = C \sqrt{(N_x/L_x)^2 + (N_y/L_y)^2 + (N_z/L_z)^2}\ /2$$

where

f=resonant frequency (Hz)

N_x, N_y, N_z=ordinal modes in the directions of X, Y and Z, respectively

L_x, L_y, L_z=dimensions in the directions of X, Y and Z in the machine compartment 7, that is, D, W and H, respectively

C=sound velocity

Frequencies f_x, f_y and f_z of a first standing wave in the respective directions of X, Y and Z can be obtained from the above equation. More specifically, when the depth D is determined to be 200 mm with the width W and height H 600 mm and 200 mm, respectively, the frequency f_x of the first standing wave of a fundamental wave in the direction of X can be obtained as:

$$\begin{aligned} f_x &= 340 \sqrt{(1/0.2)^2}\ /2 \\ &= 850 \text{ Hz} \end{aligned}$$

where

$N_y = N_z = 0$

C=340 m/sec

Similarly, the frequencies f_y and f_z of the first standing wave of the fundamental wave in the respective directions of Y and Z can be obtained as:

$$\begin{aligned} f_y &= 340 \sqrt{(1/0.6)^2}\ /2 \\ &= 283 \text{ Hz} \end{aligned}$$

$$\begin{aligned} f_z &= 340 \sqrt{(1/0.2)^2}\ /2 \\ &= 850 \text{ Hz} \end{aligned}$$

Consequently, the standing wave of the noise in the machine compartment 7 holds for the mode of the direction of Y (direction of the width) in the frequency band below the target frequency (700 Hz) and therefore, the noise produced in the machine compartment 7 may be considered a one-dimensional plane traveling wave. Consequently, the theoretical handling of the wave front can be rendered easy when the noise is to be attenuated by way of the active noise control using the speaker 13 and the like, and the attenuation control can be performed with ease and accuracy.

Referring now to FIG. 1, an acoustic signal S_e generated by the microphone 14 is supplied to an adaptive control circuit 17 of the opposite phase sound producing circuit 15 to be used for the adaptive control. The principle of the adaptive control will be described with reference to FIGS. 9 to 11. The speaker 13 is adapted to receive a white noise signal from a white noise generator 19 through a switch 18. When the switch 18 is on, a white noise putting out approximately constant energy in a preselected frequency band width is produced from the speaker 13. The switch 18 is set so as to be turned on at a predetermined timing in the condition that the compressor 8 is not driven. The white noise signal from the white noise generator 19 is supplied to a first adaptive filter 20. Based on the white noise signal from the white noise generator 19 and a cancellation signal 0 from the microphone 14, an acoustic transfer signal G_{ao} between the speaker 13 and the microphone 14 is measured by the first adaptive filter 20.

A vibrational sound signal M generated by the vibration sensor 12 is multiplied by the acoustic transfer signal G_{ao} and then, supplied to a second adaptive filter 21. Based on a signal M G_{ao} obtained by multiplying the vibrational sound signal M by the acoustic transfer signal G_{ao} and the cancellation signal 0 from the microphone 14, the second adaptive filter 21 operates to obtain the difference ΔG between an acoustic transfer function G for performance of the active noise control and the latest acoustic transfer function G_{new} obtained by the present adaptive control, as will be described later. In this respect, the acoustic transfer function G has an initial value or the value obtained by the last adaptive control and the acoustic transfer function G_{ao} has a present value obtained by the first adaptive filter 20. In consideration of driving of the compressor 8, the vibrational sound signal M from the vibration sensor 12, the cancellation signal 0 from the microphone 14 and the sound A produced from the speaker 13 may be represented as follows:

$$M = S \cdot G_{sm} \tag{5}$$

where G_{sm}=an acoustic transfer function from the compressor 8 to the vibration sensor 12

$$O = S \cdot G_{so} + A \cdot G_{ao} \tag{6}$$

where G_{so}=an acoustic transfer function from the compressor 8 to the microphone 14

$$A = M \cdot G \tag{7}$$

Furthermore, a path from the vibration sensor 12 to the microphone 14 through the second adaptive filter 21 may be represented as follows:

$$M \cdot G_{ao} \Delta G = 0 \tag{8}$$

Expanding the equation (8),

$$\begin{aligned} G &= O/(M \cdot G_{ao}) = (S \cdot G_{so} + A \cdot G_{ao}) = \\ &\quad (S \cdot G_{so} + M \cdot G \cdot G_{ao})/(M \cdot G) \\ &= (S \cdot G_{so})/(M \cdot G_{ao}) + (M \cdot G \cdot G_{ao})/(M \cdot G_{ao}) \\ &= (S \cdot G_{so})/(S \cdot G_{sm} \cdot G_{ao}) + G = (G_{so}/G_{sm})/G_{ao} + G \end{aligned}$$

Since it can be considered that $G_{so}/G_{sm} = G_{mo}$, $\Delta G = G_{mo}/G_{ao} + G$

When G_{new} is considered a suitable acoustic transfer function,

$$-G_{mo}/G_{ao} = G_{new}$$

Accordingly, since $\Delta G = -G_{new} + G$, G_{new} can be represented as $G_{new} = G - \Delta G$. Consequently, after the acoustic transfer function G is changed to G_{new}, the active noise control is performed based on the acoustic transfer function G_{new}, whereby an optimum noise attenuating effect can be maintained with real-time coefficient changes.

In order to actually operate an adaptive control system shown in FIG. 9, the switch **18** is turned on at the predetermined timing in the condition that the compressor **8** is not driven, as shown in FIG. **10**. The white noise signal from the white noise generator **19** is supplied to the speaker **13**, which produces the white noise at a predetermined level. The first adaptive filter **20** operates to obtain the acoustic transfer function G_{ao} between the speaker **13** and the microphone **14**, which function satisfies the acoustic transfer equation, $0=A\cdot G_{ao}$. Upon drive of the compressor **8**, the second adaptive filter **21** operates to obtain ΔG based on G_{ao} obtained by the first adaptive filter **20**, as shown in FIG. **11**. G_{new} is obtained based on ΔG obtained by the second adaptive filter **21** and then, the active noise control is executed based on G_{ao} obtained.

Functions of the opposite phase sound producing circuit **1** including the operational unit **16** and the adaptive control circuit **17** will now be described with reference to FIG. **3**. The operational unit **16** executes an active noise control routine in which the speaker **13** is driven in accordance with the result of the operation based on the above-described active noise control principle, at a step **P1**, so that the artificial cancellation sound from the speaker **13** is caused to interfere with the noise from the compressor **8**, thereby attenuating the noise. Such a noise attenuating operation is performed continuously. During the execution of the active noise control, the adaptive control circuit **17** operates to monitor an amount of noise attenuated by the speaker **13** based on the electrical signal S_e from the microphone **14** at every timing that the artificial sound from the speaker **17** approximates to a peak value, that is, at every timing that the level of the noise from the compressor **8** periodically changing in accordance with the power supply frequency of the compressor **8** approximates to a peak value, at steps P2 and P3. Since the electrical signal S_e is supplied to the control circuit **17** in synchronism with the power supply frequency, the amount of the attenuated noise indicated by the supplied electrical signal S_e is escaped from an influence of an external noise and therefore, is highly reliable. The adaptive control circuit **17** operates to determine whether the amount of noise thus monitored is above or below a predetermined level, at a step **P4**. When the monitored amount of noise is above the predetermined level, that is, when the amount of noise attenuated by the speaker **13** is sufficient, the adaptive control circuit **17** returns to the above-described active noise control routine, at the step **P1**. When the monitored amount of noise is below the predetermined level or when the amount of noise attenuated by the speaker **13** is insufficient and the noise is increased, the adaptive control circuit **17** operates to perform the adaptive control routine in which an operational coefficient (acoustic transfer function) of the operational unit **16** is varied by a predetermined amount so that the amount of noise attenuated by the speaker **13** is increased, at a step **P5**, and thereafter, returns to the active noise control routine (the step **P1**).

In the embodiment, the microphone **14** and the speaker **13** are integrally connected by a connecting member **22** so that occurrence in the variations of the distance between them is prevented, as shown in FIG. **2**. The connecting member **22** comprises a speaker box **23** to which the speaker **13** is secured and a support arm **24** projected from the speaker box **23**. The microphone **14** is secured to the distal end of the support arm **24**. The speaker box **23** is embedded in an inner wall of the machine compartment **7** or the heat-insulative bottom wall of the cabinet **1**. Thus, the speaker **13** and the microphone **14** are simultaneously disposed in the respective predetermined positions in the machine compartment **7**. Although the speaker **13** is secured at one side of the speaker box **23** and the support arm **22** on which the microphone **14** is mounted is secured at the opposite side of the speaker box **23** to ensure the distance between the speaker **13** and the microphone **14**, in the embodiment, the noise attenuation system is stable without occurrence of howling irrespective of the distance between them. Accordingly, the distance between them is determined based on the wave shape of the acoustic transfer function G_{ao} (coherence function) and an amount of noise to be attenuated. The distance between them is adjusted by changing any one of the length of the support arm **24**, the distance between the support arm **24** and the speaker **13** and an angle θ between the speaker box **23** and the support arm **24**.

A microphone amplifier (not shown) for the microphone **14** is disposed in the speaker box **23** so that the distance or the length of a cable between the microphone **14** and the amplifier is reduced. As the sound pressure at the position of the microphone **14** is gradually reduced by the adaptive control, it becomes difficult to accurately detect a weak acoustic signal. More specifically, if the distance between the microphone **14** and the microphone amplifier is long, an electrical noise is superposed on the cable between them, which reduces accuracy of the detection of the weak acoustic signal. This causes reduction of the adaptive control accuracy and accordingly, the amount of noise attenuated is decreased. To solve this problem, the microphone amplifier is disposed in the speaker box so that the distance or length of the cable between the microphone **14** and the amplifier is reduced, as is described above. Consequently, the acoustic signal detection accuracy is improved and furthermore, the speaker box **23** interior is effectively used.

In accordance with the above-described embodiment, the speaker **13** and the microphone **14** are integrally connected with each other by the connecting member **22**. Accordingly, when the speaker **13** and the microphone **14** are disposed in the machine compartment **7**, these members can be disposed in the machine compartment 7 without using any specific jig with the predetermined positional relationship therebetween exactly maintained. Consequently, occurrence of the variations in the distance between the speaker **13** and the microphone **14** can be prevented, which improves the accuracy of the adaptive control. Furthermore, since the speaker **13** and the microphone **14** are simultaneously disposed in the machine compartment **7**, the working efficiency can be improved as compared with the case where these members are separately disposed in the machine compartment **7**, which provides the cost reduction.

Although the speaker box **23** is embedded in the heat-insulative bottom wall of the cabinet **1** in the foregoing embodiment, it may be disposed in the machine compartment **7**. Furthermore, although the vibration sensor **12** is employed as the detection means for detecting the noise produced in the machine compartment **7**, a microphone may be employed instead.

FIG. **12** illustrates a second embodiment of the invention. The rear cover **11** of the machine compartment **7** is utilized as the connecting member integrally connecting the active noise control speaker **51** and the noise attenuation monitoring microphone **52**. The speaker box **53** of the speaker **51** and the microphone **52** are mounted at respective predetermined positions on the inside of the rear cover **11**. The other construction is the same as that in the foregoing embodiment.

In accordance with the second embodiment, the rear cover **11** serves as the connecting member integrally connecting the speaker **51** and the microphone **52**. Accordingly, the same effect can be achieved as in the foregoing embodiment. Furthermore, since the speaker **51** is not embedded in the heat-insulative bottom wall of the cabinet **1**, the thickness of the cabinet bottom wall need not be increased and the compartment volume of the cabinet **1** is prevented from being reduced. Furthermore, even if the compressor **8** and the complicated piping are provided in the machine compartment **7**, the inspection and maintenance for the speaker **51** and the microphone **52** may be readily performed when the rear cover **11** is detached. Since the provision of the above-described noise attenuation system does not necessitate alteration of the construction of the heat-insulative cabinet **1**, an excessive cost is not needed. When the design of the machine compartment **7** is standardized, the noise attenuation system may be applied to the refrigerators of the different types.

Although the noise attenuation system is applied to the household refrigerator in the foregoing embodiments, it may be applied to an outdoor unit of a room air conditioner or a refrigerative show case.

The foregoing disclosure and drawings are merely illustrative of the principles of the present invention and are not to be interpreted in a limiting sense. The only limitation is to be determined from the scope of the appended claims.

We claim:

1. A refrigerating apparatus having noise, attenuation comprising:

a heat-insulative cabinet having a storage compartment and a machine compartment;

a compressor provided in the machine compartment;

sound detection means, provided in the machine compartment, for detecting noise produced by operating the compressor and converting the detected noise to a corresponding electrical signal, the detected noise having a first phase;

an operational unit, electrically coupled to the sound detection means, for converting the electrical signal provided by the sound detection means to an acoustic signal to perform active noise control;

a cancellation sound producer for producing, responsive to the acoustic signal, a sound having a second phase opposite to the first phase of the noise to attenuate the noise;

a noise attenuation monitoring sound receiver for monitoring a noise attenuating effect of the cancellation sound producer and providing an attenuation value relating to the noise attenuating effect;

an adaptive control circuit, electrically coupled between the noise attenuation monitoring sound receiver and the operational unit, for adjusting an operating condition of the operational unit by a predetermined amount when the attenuation value is out of a predetermined tolerance, the adaptive control circuit repeatedly adjusting the operating condition of the operational unit until the attenuation value comes within the predetermined tolerance; and

means for fixing the cancellation sound producer and the noise attenuation monitoring sound receiver at a first predetermined distance apart.

2. A refrigerating apparatus according to claim **1**, wherein the fixing means is a rear cover, detachably mounting to the refrigeration apparatus, to cover a rear opening of the machine compartment.

3. A refrigerating apparatus according to claim **1**, wherein the cancellation sound producer is embedded in an heat-insulative wall defining the machine compartment.

4. A refrigerating apparatus according to claim **1**, wherein the sound detection means comprises a vibration sensor mounted on the compressor.

5. A refrigeration apparatus according to claim **1**, wherein the machine compartment is defined by first, second and third dimensions, the first dimension being larger than the second and the third dimensions to cause the sound to form a standing wave propagating in the direction of the first dimension.

6. A refrigerating apparatus according to claim **2**, wherein the rear cover of the machine compartment has a ventilating opening formed therein at a second predetermined distance away from the compressor and the noise attenuation monitoring sound receiver is disposed proximate to the ventilating opening in.

7. A refrigerating apparatus according to claim **2**, wherein the rear cover of the machine compartment comprises material having predetermined heat-conductivity and predetermined sound-transfer loss properties.

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